Interaural Difference of Wave V Predicting Postoperative Hearing in Gardner–Robertson Class II Acoustic Neuroma Patients

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J Neurol Surg B 2013;74:274–278.

Abstract

Patients with acoustic neuroma classified in Gardner and Robertson (GR) Class II should be considered to have useful hearing, and patients classified in Class III should be considered to have not-useful hearing. Therefore, it is important for acoustic neuroma surgery to distinguish between postoperative GR Class II and Class III patients by brainstem auditory evoked potentials (BAEPs). We evaluate which BAEP parameter is the best for predicting postoperative GR Class II or III in 36 preoperative GR Class II patients with unilateral acoustic neuroma. Delay in wave V latency, reduction ratio in wave V amplitude, and interaural difference of wave V (IT5) are evaluated by a receiver-operating characteristic (ROC) curve in this study. IT5 is the best distinguishing parameter between postoperative Class II and Class III. IT5 below 1.12 millisecond (msec) should be a good marker to preserve postoperative useful hearing. Thus, comparing the latency of wave V on both sides is important, and surgeons would be able to make more informed decisions during surgery by checking IT5 on BAEPs.

Keywords

- acoustic neuroma
- brainstem auditory evoked potentials
- useful hearing
- interaural difference of wave V

Introduction

Hearing preservation is an important goal in acoustic neuroma surgery, and neurophysiological intraoperative monitoring is important. Brainstem auditory evoked potentials (BAEPs) are a common technique for intraoperative monitoring. BAEP findings have been widely investigated as potential predictors for hearing preservation.[1–5] However, no consensus has been reached on which BAEP findings during acoustic neuroma surgery best predicts hearing after surgery. With reliable and standardized predictors for hearing after surgery, surgeons would be able to make more informed decisions during surgery. In 1988, Gardner and Robertson developed a classification scheme in which patients were stratified into one of five categories depending on the results of audiometric studies.[6] They concluded that patients classified in Classes I and II should be considered to have useful hearing and that patients classified in Class III should be considered to have not-useful hearing. To preserve postoperative useful hearing, it is important to distinguish between postoperative Class II and Class III patients by intraoperative BAEPs. Our interest was in exploring the most effective discriminating BAEP parameters between postoperative Class II and III, and we undertook this study accordingly.

Methods

We received approval from the Nagoya City University Medical School investigational review broad to collect pertinent data from the records.

Patients

From March 2004 to December 2012 a total of 199 patients underwent surgery for unilateral acoustic neuroma at Nagoya City University Medical School Hospital. Pure tone average

received
June 7, 2012
accepted after revision
April 7, 2013
published online
June 13, 2013

DOI http://dx.doi.org/10.1055/s-0033-1348024.
ISSN 2193-6331.

and speech discrimination testing were performed 1 to 7 days before surgery and approximately 2 weeks after surgery. The results were evaluated according to the Gardner–Robertson classification (GR Class). We retrospectively analyzed their medical records.

We suggest that intraoperative BAEP parameters will dramatically change when preoperative GR Class I acoustic neuroma patients change hearing category from Class I to Class III. By contrast, BAEP parameters will change only a little when preoperative GR Class II acoustic neuroma patients change hearing category from Class II to Class III. To identify postoperative GR Class III patients by BAEPs, discrimination among preoperative GR Class II patients must be hard compared with discrimination among preoperative GR Class I patients. Therefore, the point to be investigated is which BAEP parameters in preoperative GR Class II patients can discriminate between postoperative Class II and III. Thus, the criteria for inclusion in this study were GR Class II before surgery and GR Class II or III after surgery. Thirty-six patients were eligible. The patients' ages ranged from 24 to 67 years, with an average of 48.4 years. Fifteen patients underwent surgery via the middle cranial fossa approach and 21 patients via the retrosigmoid approach. Fourteen patients were classified as postoperative GR Class II and 22 patients as postoperative GR Class III.

Intraoperative BAEP Findings

During surgery, all patients underwent simultaneous and continuous monitoring of BAEPs using Nicolet Viking Selection (VIASYS, Dublin, Ohio, USA). The stimuli used are clicks presented at a rate of 19.7 Hz and an intensity level of 100 dB. During surface BAEP recording, responses of 2,000 sweeps were averaged. The monitoring technique has been detailed elsewhere.[7]

The latency and amplitude of wave V were measured on intraoperative BAEPs. The amplitude of wave V was measured from the positive peak of wave V to the next negative peak.[8] The delay in wave V latency and the reduction ratio in wave V amplitude were calculated respectively as follows:

$$\text{intraoperative delay in wave V latency} = \text{latency of wave V at the time of the conclusion of surgery (wave V}\textit{conclusion}\text{)} - \text{latency of wave V at the time of initiation of surgery (wave V}\textit{initiation}\text{)}$$

$$\text{intraoperative reduction ratio in wave V amplitude} = \frac{\text{amplitude of wave V}\textit{conclusion}}{\text{amplitude of wave V}\textit{initiation}}$$

In most cases, BAEPs were recorded by only tumor side stimulation. To analyze interaural difference of wave V (IT5) during surgery, we calculated contralateral latency of wave V (non-tumor side) during surgery from BAEP data at the physiological laboratory room. BAEPs were recorded in all patients approximately 1 week before surgery at the physiological laboratory room. The equipment and stimulus parameters at the laboratory room were different from intraoperative monitoring. The stimuli were delivered through headphones at the laboratory room. Because the stimuli were delivered via the tube from the sound generator during surgery, waves were overdue for approximately 2 msec compared with those at the laboratory room. This delay time was calculated by the following formula:

$$\text{delay time} = \text{latency of wave V}\textit{initiation} - \text{latency of wave V (tumor side) at the laboratory room}$$

Then, contralateral latency of wave V (non-tumor side) during surgery is calculated by the following formula:

$$\text{contralateral latency of wave V (non-tumor side) during surgery} = \text{contralateral latency of wave V (non-tumor side) at the laboratory room} + \text{delay time}$$

Subsequently, IT5 during surgery was evaluated as follows:

$$\text{IT5 during surgery} = \text{latency of wave V}\textit{conclusion} - \text{contralateral latency of wave V (non-tumor side) during surgery}$$

Statistical Analyses

Statistical analysis was performed using R-2.14.0 (R Foundation, Vienna, Austria). Receiver operating characteristic (ROC) curves were plotted using EPI 1.0.12 software, developed by Carstensen and colleagues. Area under curves (AUCs) and cutoff values were evaluated. Analysis for difference was performed using Wilcoxon signed-rank test. Statistical significance was set at $p < 0.05$.

Results

Latency of Wave Vinitiation

Wave V could not be detected at the time of initiation of surgery in two patients, although they had useful hearing. Useful hearing could be preserved in one patient and wave V recovered at the time of conclusion of surgery. Latency of wave V*initiation* could be estimated in 34 patients. The median preoperative latency of wave V*initiation* was 7.64 msec in postoperative GR Class II ($n = 13$) and 8.36 msec in postoperative GR Class III ($n = 21$) (►**Table 1**). There was a significant difference between postoperative GR Class II and Class III ($p = 0.03$).

Intraoperative Delay in Wave V Latency

Wave V*initiation* could not be detected in two patients (postoperative GR Class II; $n = 1$, Class III; $n = 1$). Wave V*conclusion* could not be detected in seven patients (postoperative GR Class II; $n = 2$, Class III; $n = 5$). Wave V appeared at the time of the conclusion of surgery in one patient in postoperative GR Class II. Because the latency of wave V*initiation* could not be measured in this patient, intraoperative delay could not be estimated. Therefore, in total, intraoperative delay was estimated in 11 postoperative GR Class II patients and 17 postoperative GR Class III patients. Among these patients, the median intraoperative delay in wave V latency was 0.12 msec in postoperative GR Class II ($n = 11$) and 0.24 msec in postoperative GR Class III ($n = 17$) (►**Table 1**). There was no significant difference between postoperative GR Class II and Class III. Analysis using the ROC curve demonstrated that AUC was 0.53. The cutoff value was 0.56 msec (►**Fig. 1**).

Table 1 Intraoperative BAEPs findings

	Latency of wave V*initiation* (msec)	Delay in wave V latency (msec)	Reduction ratio in wave V amplitude	Interaural difference of wave V (msec)
Postop GR Class II	7.64* ($n = 13$)	0.12 ($n = 11$)	0.83 ($n = 13$)	0.3** ($n = 11$)
Postop GR Class III	8.36* ($n = 21$)	0.24 ($n = 17$)	0.43 ($n = 21$)	2.05** ($n = 16$)

Abbreviations: BAEP, brainstem auditory evoked potentials; GR, Gardner and Robertson.
*Significant difference between postoperative GR Class II and Class III ($p = 0.03$) by Wilcoxon signed-rank test.
**Significant difference between postoperative GR Class II and Class III ($p = 0.04$) by Wilcoxon signed-rank test.

Intraoperative Reduction Ratio in Wave V Amplitude

Two patients were excluded because wave V*initiation* could not be detected, and intraoperative reduction ratio in wave V amplitude was estimated in 34 patients. The reduction ratio was estimated as zero if wave V disappeared at the time of the conclusion of surgery. Intraoperative median reduction ratio in wave V amplitude was, respectively 0.83 in postoperative GR Class II ($n = 13$) and 0.43 in GR Class III ($n = 21$) (►**Table 1**). There was not a significant difference. Analysis using the ROC curve demonstrated that AUC was 0.58. The cutoff value was 0.59 (►**Fig. 2**).

Interaural Difference of Wave V (IT5) during Surgery

IT5 during surgery could be estimated in 27 cases. Latency of wave V*initiation* could not be estimated in one postoperative GR Class II and one postoperative GR Class III patient. Latency of wave V at the laboratory room could not be estimated in another postoperative GR Class III patient. Latency of wave V*conclusion* could not be estimated in two other postoperative GR Class II and four postoperative GR Class III patients. Finally, IT5 during surgery could be estimated in 11 postoperative GR Class II and 16 postoperative GR Class III patients. Median IT5 during surgery was 0.3 msec and 2.05 msec in postoperative GR Class II and Class III, respectively (►**Table 1**). There was a significant difference between postoperative GR Class II and Class III ($p = 0.04$). Analysis using the ROC curve demonstrated that AUC was 0.74. IT5 during surgery of 1.12 msec constituted the cutoff value for useful hearing with 75.0% sensitivity and 90.9% specificity (►**Fig. 3**).

Verification of the Cutoff Value in IT5 during Surgery

We verified this cutoff value in IT5 during surgery with all patients' BAEP findings. After surgery, 76 patients had useful hearing (postoperative GR Class I or II) and IT5 during surgery could be estimated in 73 patients. IT5 during surgery was below 1.12 msec in 63 patients, and it was 1.12 msec and more in 10 patients. Twenty-four patients were classified in postoperative GR Class III, and IT5 during surgery could be estimated in 18 patients. IT5 during surgery was below 1.12 msec in four patients and it was 1.12 msec and more in 14 patients. Wave V*conclusion* could be detected in two postoperative GR Class IV patients, but there was no case showing below 1.12 msec IT5 during surgery among postoperative GRIV or V patients. Thus, in 94% (63/67), postoperative useful hearing was achieved in IT5 during surgery was below 1.12 msec. In only 38% (10/26),

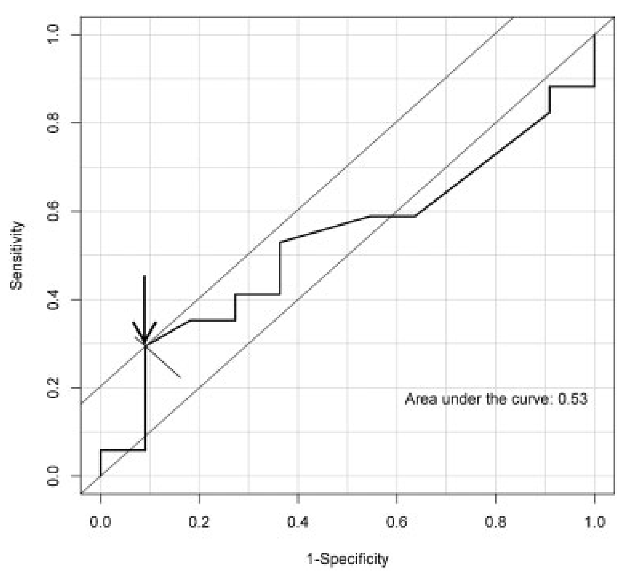

Fig. 1 A receiver operating characteristic (ROC) curve of intraoperative delay in wave V latency. Arrow indicates cutoff point.

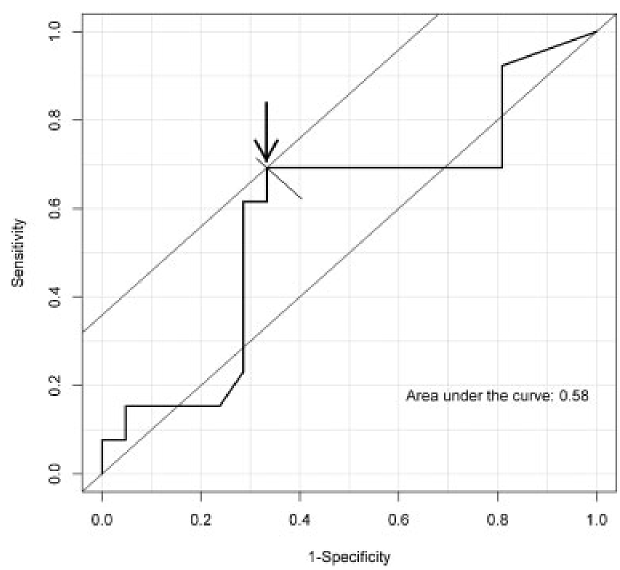

Fig. 2 A receiver operating characteristic (ROC) curve of intraoperative reduction ratio in wave V amplitude. Arrow indicates cutoff point.

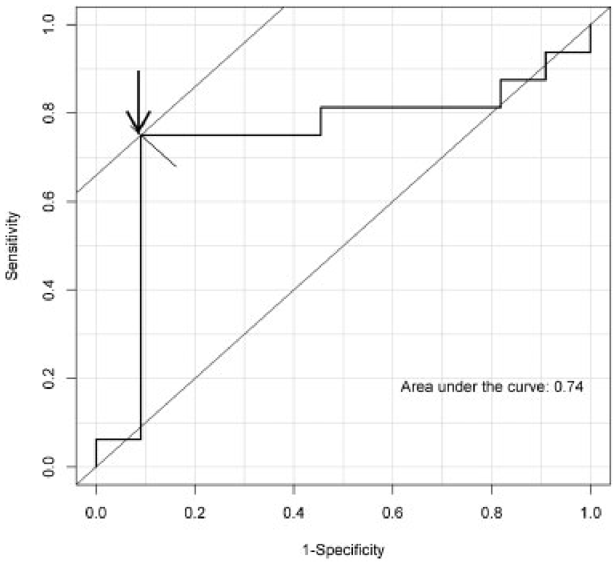

Fig. 3 A receiver operating characteristic (ROC) curve of interaural difference of wave V (IT5) during surgery. Arrow indicates cutoff point.

postoperative useful hearing was achieved in IT5 during surgery was 1.12 msec and more.

Discussion

BAEPs have been the most widely employed monitoring method during acoustic neuroma surgery. The recorded waves corresponding to the auditory tract to the brainstem are Waves I to V. Damage to the cochlear nerve results in a delay in latency and a reduction in the amplitude of Wave V. When this delay becomes significant, the neurophysiologist must inform the surgeon so that the procedure is stopped until the cause is identified and the precipitating factors are corrected. For most clinical neurophysiologists involved in BAEP monitoring during surgery of the cerebellopontine angle, the latency of wave V is considered the best electrophysiological indicator for signaling cochlear nerve damage resulting from operative manipulations. Three levels of warning signals on BAEP monitoring during microvascular decompression (MVD) for hemifacial spasm have been established to provide information on postoperative hearing function.[9] Although there have been many studies concerning wave V on BAEPs in acoustic neuroma patients,[1–3,5,10] reliable and standardized signals for cochlear nerve damage have not yet been established.[11,12]

The AUCs of the intraoperative delay in wave V latency was less than 0.6. AUC between 0.50 and 0.70 or so represent rather low accuracy. AUC between approximately 0.70 and 0.90 represent accuracies that are useful for some purposes, and higher values of AUC indicate higher accuracy.[13] Therefore, interaural difference of wave V (IT5) during surgery can predict postoperative hearing with moderate accuracy. The other two parameters during surgery have reduced accuracy for predicting postoperative hearing. Hearing function is already damaged in various ways by tumor even if preoperative hearing is useful in the case of GR Class II patients. In fact, the latency of wave V*initiation* in postoperative GR Class II patients differed significantly from that in postoperative GR Class III patients. Measurement of intraoperative delay may only reflect intraoperative damage. A maximum permissible delay in wave V latency for preserving useful hearing must be different in each patient. Thus, delay in wave V latency during surgery cannot serve as a reliable predictor for postoperative hearing, at least in the case of GR Class II patients. Similarly, we found that the reduction ratio in wave V amplitude was not a good predictor for postoperative hearing. For noncerebellopontine angle tumor surgery, hearing loss usually occurred when wave V permanently disappeared. The presence or absence of Wave V during MVD has significantly correlated to hearing outcome.[11] For acoustic neuroma surgery, the absence of wave V correlates with hearing loss and the presence of wave V correlates to hearing preservation.[10] It appears that the degree of reduction in wave V amplitude does not always correlate to the degree of hearing disturbance in acoustic neuroma surgery in this study. BAEPs are far-field evoked potentials with a poor signal-to-noise ratio, and power line noise and electromyography during monitoring often affects them. Power line noise and electromyography affect the amplitude of waves. The reduction ratio was zero in one postoperative GR Class II patient in our study. Furthermore, wave V could not be detected in two patients at the time of initiation of surgery even though they had useful hearing. Similar BAEP findings have been previously reported.[4] The absence of wave V does not preclude useful hearing after surgery. Consequently, the amplitude of wave V may be an unreliable parameter. Monitoring of cochlear nerve action potential (CNAP) must be useful on such an occasion. Because CNAP is less affected by electrical artifact, the large amplitude potential can be visualized.[7]

On the other hand, IT5 during surgery is a good predictor. Measuring interaural latency of wave V (IT5) helped in identifying acoustic neuroma before the development of MRI.[14] We can estimate both preoperative and intraoperative damage by measuring IT5. The optimal cutoff value analyzed by an ROC curve was 1.12 msec. This value is similar to "critical warning" (1 msec delay of wave V) determined by experience in monitoring BAEPs during MVD for hemifacial spasm.[15] This cutoff value showed good predictive performance. Among all the GR Classes, in 94% postoperative useful hearing was achieved in IT5 during surgery was below 1.12 msec. We did not actually measure contralateral BAEPs during surgery in all cases, and we presumed contralateral latency of wave V (non-tumor side) during surgery by adding the difference between values obtained in the operating room and the laboratory. IT5 during surgery was estimated using the hypothetical contralateral latency of wave V (non-tumor side). Recently, we recorded contralateral BAEPs in the operating room. The actual latency (non-tumor side) is almost the same as the hypothetical latency, and this hypothetical contralateral latency of wave V (non-tumor side) calculated from preoperative BAEPs may be substitutable. However, when wave V (tumor side) cannot be detected at the time of initiation of surgery (as in two patients in this study), the contralateral latency of wave V (non-tumor side) cannot be calculated. Furthermore, it is probable that the latency of wave V (tumor side) will change with time prior to surgery. Usually, hearing will not change significantly within approximately 1 week, but it can happen. At that time, hearing will be worse in most cases, and the latency of wave V (tumor side) will be delayed. Because the difference between measures in the operating room and the laboratory increase, the hypothetical contralateral latency of wave V (non-tumor side) will be delayed compared with the actual latency of wave V (non-tumor side). Then, IT5 during surgery will be underestimated. Accordingly, BAEPs should be recorded in the operating room using stimulation on both sides.

Conversely, IT5 during surgery could be measured in only 75% (28/32) of patients, and this is a significant limitation because a quarter of the whole can not be estimated. If wave V cannot be detected during surgery, IT5, of course, cannot be estimated. We also monitor CNAP with the microdissector and frequently check CNAP in the event wave V cannot be detected. From our experience, CNAP can accurately predict postoperative hearing.[7] We usually recorded CNAP when the BAEPs changed. Comonitoring of CNAP and BAEPs, especially evaluating IT5, is useful for making more informed decisions during surgery. Our goal for acoustic neuroma surgery is to first adequately remove the tumor to preserve life, second to preserve facial nerve function, and third to preserve hearing. Therefore, if neither wave V nor CNAP can be detected in the early stage of surgery, we try to remove as much tumor as possible while preserving facial nerve function. If the latency of wave V is increased and IT5 comes close to 1.12 msec in the last stage of surgery, we will stop to remove the tumor and give priority to hearing preservation. We did not always pursue the total removal of the tumor. Otolaryngologists and neurosurgeons discuss the goal of each case during surgery based on BAEPs and CNAP in our hospital.

Intraoperative delay and the amplitude of wave V are common BAEP parameters during acoustic neuroma surgery. However, we would like to emphasize that comparing the latency of wave V on both sides is important to predict postoperative hearing, especially for GR Class II patients. Although measurement of the interaural difference of wave V is simple, to our knowledge, this is the first report showing IT5 is a very good predictor of postoperative hearing in acoustic neuroma surgery. Surgeons would be able to make more informed decisions during surgery by checking IT5 on BAEPs.

Conclusions

Although absence of wave V does not preclude useful hearing after surgery, measurement of interaural difference of wave V (IT5) is important and a good predictor for postoperative hearing in GR Class II acoustic neuroma patients. Intraoperative IT5 below 1.12 msec should be a good marker for preserving useful hearing after surgery.

Acknowledgments

We are thankful to the physiological laboratory staff and the Medical Engineering Team in the operating room of Nagoya City University Hospital for their generous support with monitoring of BAEPs.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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